Predicting the Impact of Seabed Uncertainty and Variability on Propagation Uncertainty

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LONG TERM GOALS

Develop capability for quantifying, predicting and exploiting (QPE) the impact of seabed uncertainty on sonar system performance.

OBJECTIVES

The objectives are to: 1) develop techniques required to create a 2D geoacoustic uncertainty model (2D-GeUM) over an operationally significant area, 2) demonstrate techniques to create 2D-GeUM in area off northeast coast of Taiwan, and 3) demonstrate ability of 2D-GeUM to predict propagation uncertainty.

APPROACH

In order to predict the impact of seabed geoacoustic uncertainties and variability on propagation uncertainty along a radial of interest, a 2D geoacoustic uncertainty model (2D-GeUM) is required. Such a model quantifies depth- and range-dependent geoacoustic properties and their uncertainties over the area of interest. For the QPE experiment, this will be in an area northeast of Taiwan, ~50 km x 50 km, including part of the Chilung shelf, the East China Sea shelf and upper slope.

The approach exploits direct-path wide-angle seabed reflection data and geologic modeling as the basis for generating the 2D-GeUM. The components of the approach are shown in cartoon form in Figure 1. The 2D-GeUM is the key model for predicting the impact of seabed uncertainties and variability on TL uncertainties along a specified radial. Early results using data from a different shallow water area are very promising in terms of capturing the correct propagation uncertainties.

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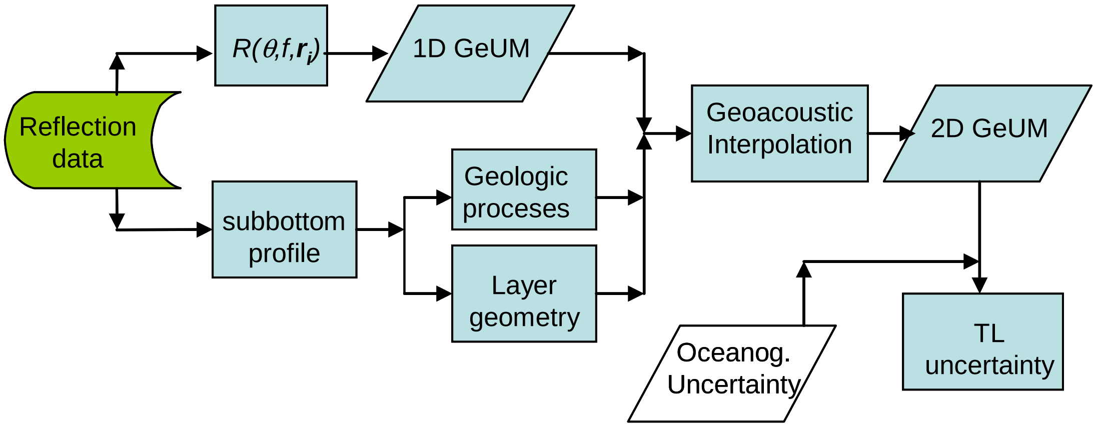

Figure 1. Approach to predicting the TL uncertainty with focus on quantifying the seabed contribution to uncertainty.

WORK COMPLETED

- identified and obtained key results from geologic-geophysical-geoacoustic literature, NE Taiwan, pertinent to DRI goals
- conducted study showing the impact of geoacoustic uncertainties from grain size maps (NE Taiwan shelf) on propagation uncertainty (uncertainties were large 50 dB at 10 km at 95% confidence).
- quantified impact of presence/absence of mud volcanoes on propagation uncertainties
- progress in quantifying perturbed physics geoacoustic uncertainties in reflection data (with Jan Dettmer and Stan Dosso, Un Victoria).
- Initial steps in geoacoustic interpolation (with Allen Lowrie, US Naval Oceanographic Office)
- refined experiment strategy with Taiwanese partners (Chi Fang), US collaborators (Jim Lynch and Phil Abbot) and Un. Victoria collaborators (Jan Dettmer and Stan Dosso)
- provided guidance on seabed uncertainty and variability issues for 2008 Pilot Experiment, in particular provided maps, suggested strategies for OMAS tracklines, and geoacoustic models.

RESULTS

Unknown acoustic boundary conditions at the seabed can lead to large uncertainties in TL and noise predictions. Spatial (and possibly temporal) variability will increase those uncertainties. As one example of this, it is often the case that a grain size estimate is available for a given area, but little other seabed data. This is the case on the mid to outer shelf in the planned main acoustic experiment box off NE Taiwan. Along the 150m contour, grab sample measurements [1] show a mean grain size of 0.0156 mm (ϕ=6). While having a mean grain size is useful, there are large uncertainties in converting a grain size to geoacoustic properties [2] as shown in Fig 2. These uncertainties then translate to large propagation uncertainties as shown in Figure 3 (using RAM); at 10 km range the

uncertainties are ~50 dB at the 95% confidence level. In some sense, this is an under-estimate of the uncertainties inasmuch as the uncertainty and variability along-track of the grain size estimate was not considered. However, in this case, the uncertainties of the geoacoustic properties are so large that these effects are likely secondary. The modeling also does not take into account sub-bottom structure which would also tend to increase uncertainties, especially at low frequencies (below 1000 Hz).

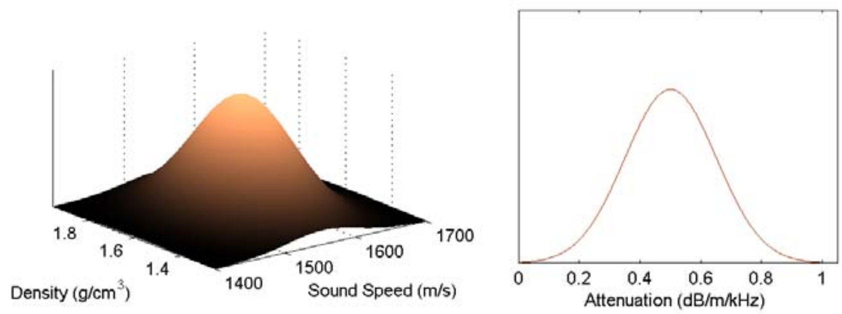

Figure 2. Predicted geoacoustic uncertainties from mean grain size measurements along the 150m contour in the proposed experiment area.

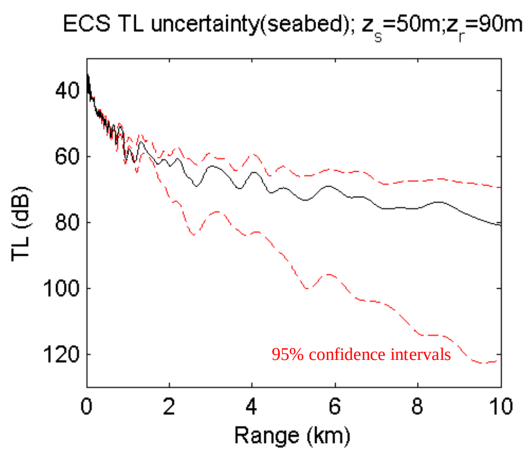

Figure 3. Predicted propagation uncertainties at 500 Hz from geoacoustic uncertainties of Fig 2 in the proposed experiment area. Bandwidth is 100 Hz.

Mud volcanoes (5-40 m in height; radii ~20-600 m) were recently discovered [3] along the outer shelf and slope of the East China Sea. Besides the bathymetric expression, the presence of gas, drastically alters seabed physical properties relative to the surrounding sediments. Some of the mud volcanoes are expected to be “active” meaning that they are actively venting methane (e.g., in bubble plumes) and/or oil into the ocean. Very little is known about the temporal scales associated with the methane fluxes. The authors concluded that given the spatial extent of the source (deep thermogenic methane) and the structural characteristics of the outer shelf and slope (many faults) that mud volcanoes and large pockmarks were likely all along the outer shelf. A brief modeling study was conducted to examine the impact of just the bathymetric component (Figure 4) on propagation. The results show order 10 dB variability with/without mud volcanoes beyond ranges of 6 km. The actual uncertainty is likely to be higher since 1) the material properties of these features may be significantly different than the surrounding seabed and 2) if the mud volcanoes are active, the concomitant bubble plumes may also have a measurable impact on propagation.

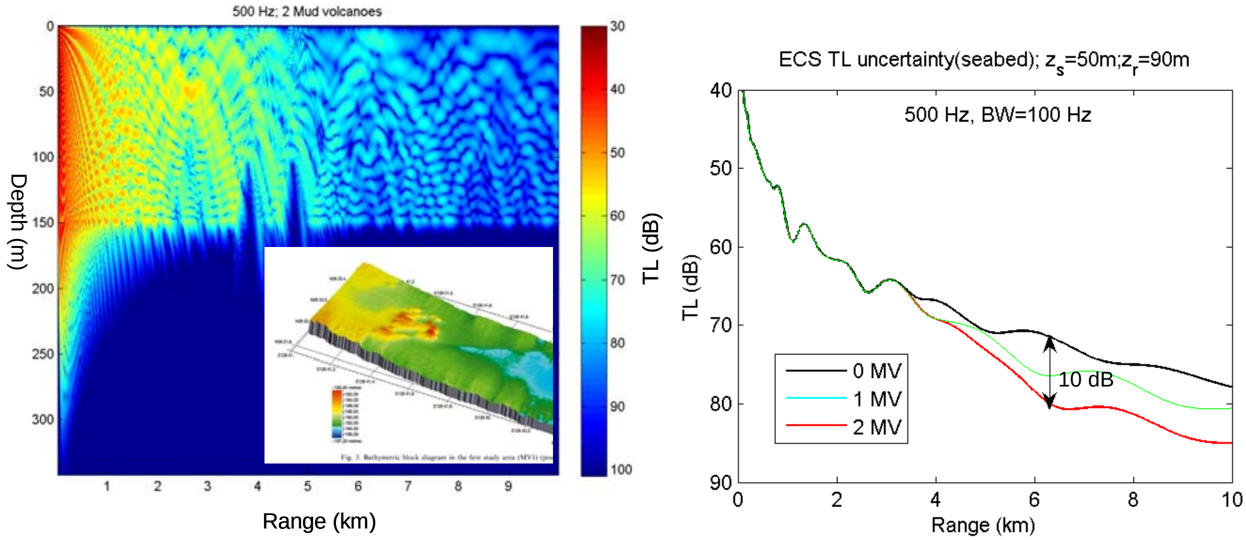

Figure 4. a) narrowband PE predictions with 2 mud volcanoes, b) inset, bathymetry on the ECS outer shelf [3] showing a cluster of mud volcanoes, c) propagation uncertainty at 500 Hz with 100 Hz bandwidth for 0,1,2 mud volcanoes including only effects of bathymetry.

IMPACT/APPLICATIONS

The results were employed to help in the siting of the 2008 pilot acoustic experiments and also provide underpinning for the main 2009 experiment. The progress in developing a perturbed physics approach to quantifying geoacoustic uncertainty has very broad implications for uncertainty estimation in the ocean acoustics community inasmuch as heretofore only a single parameterization is used for geoacoustic/parameter estimation.

RELATED PROJECTS

ONR Broadband Clutter Joint Research Project; data collected in that project is being used in QPE to test new advances in geoacoustic uncertainty quantification in preparation for the data collection effort off NE Taiwan in August 2009.

REFERENCES

[1] Composition and Texture of Surface Sediment Indicating the Depositional Environments off Northeast Taiwan, Min-Pen Chen, Shen-Chung Lo and Ken-Ling Lin, Acta Oceanographica Taiwanica (TAO), **3**, 395-418, September 1992.

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[3] Mud volcanoes at the shelf margin of the East China Sea, P. Yin, S. Berné, P. Vagner, B. Loubrieu, Z. Liu, Marine Geology, **194**, 135-149, 2003.